Evaluation of the Digital Fountain Process for Data Delivery in Space-Based Communications

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Topic Overview

- Overview of the Transmission Control Protocol (TCP)
- Overview of Digital Fountain Process
- GRC Test Methods and Equipment
- Results
- Conclusions & Lessons Learned
- Future Work

Overview of the Transmission Control Protocol (TCP)

Overview of TCP

- Developed by the Defense Advanced Research Projects Agency (DARPA) to provide communications between hosts of different vendor origins.

- Contains mechanisms to provide packet sequencing, flow control, and error recovery allowing for reliable end-to end communications.

- Has evolved to include mechanisms that allow for a greater awareness/fairness of competing network flows (RFC 2581).

- All mechanisms require timely receiver feedback in the form of an acknowledgement of data sent.

Overview of the Digital Fountain Process

Overview of the Digital Fountain Process

- Developed as a commercial product for multicast content distribution.

- Utilizes Tornado codes to generate a perpetual stream of meta-content or "beads" from the original data.

- Transmits meta content via UDP/IP multicast to efficiently disseminate data to a scalable number of receivers.

- Each receiver listens to the transmission only long enough to collect the significant number of unique beads needed to regenerate the original content.

- Receiver acknowledgement is NOT required to ensure data delivery.

GRC Test Methods and Equipment

Equipment (Host)

Digital Fountain Server

- DF Transporter application running on Linux kernel 2.4.19
- Processor: 1.4Ghz Pentium   RAM: 512MB

Digital Fountain Client

- dfcmdlinepush application running on Linux kernel 2.4.18
- Processor 450Mhz Pentium III   RAM: 512MB

TCP Server

- TTCP application running on Solaris 7
- Processor 200Mhz UltraSPARC (x2)   RAM: 256MB

TCP Client

- TTCP application running on Solaris 7
- Processor 200Mhz UltraSPARC (x2)   RAM: 512MB

Equipment (Network)

Terrestrial Network

- Hosts linked via 10BaseT-FDX to an ethernet switch.
- Switch linked via 100BaseT to a Cisco 7100 router.

Space Network

- Hosts linked via 10BaseT-FDX to an ethernet switch.
- Switch linked via 100BaseT to a Cisco 7100 router.

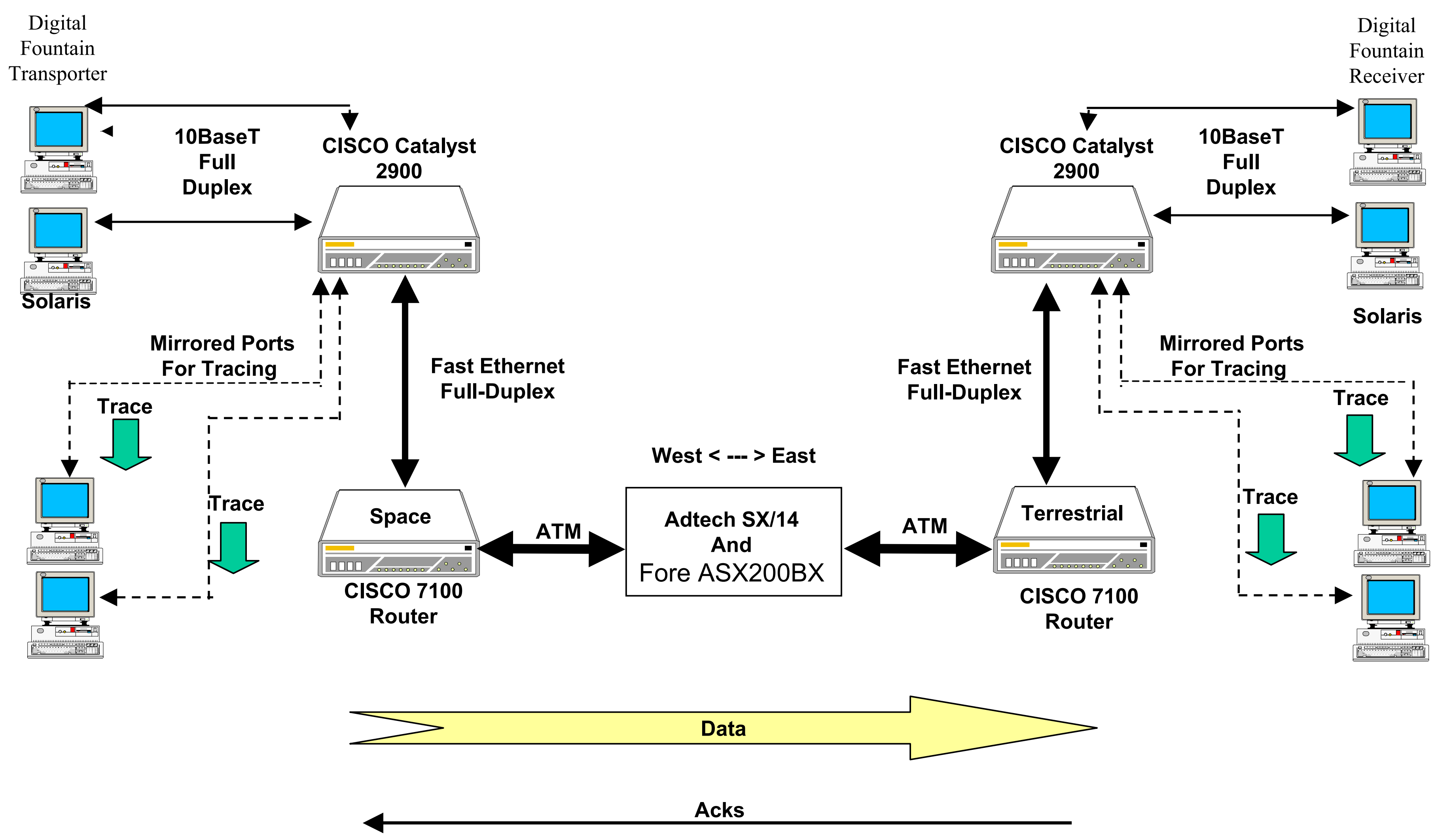
Delay, BER, and Rate Limiting

- Routers linked via OC-3 (ATM) to Adtech SX/14.

Access and Monitoring

- Monitoring systems are connected to mirrored host ports.
- Out-of-band access for all testbed systems.

Testbed Configuration



Methodology

Test with the following file sizes:

- 100k
- 1000k
- 10000k
- 100000k

Test with the following Bit Error Rates (BER):

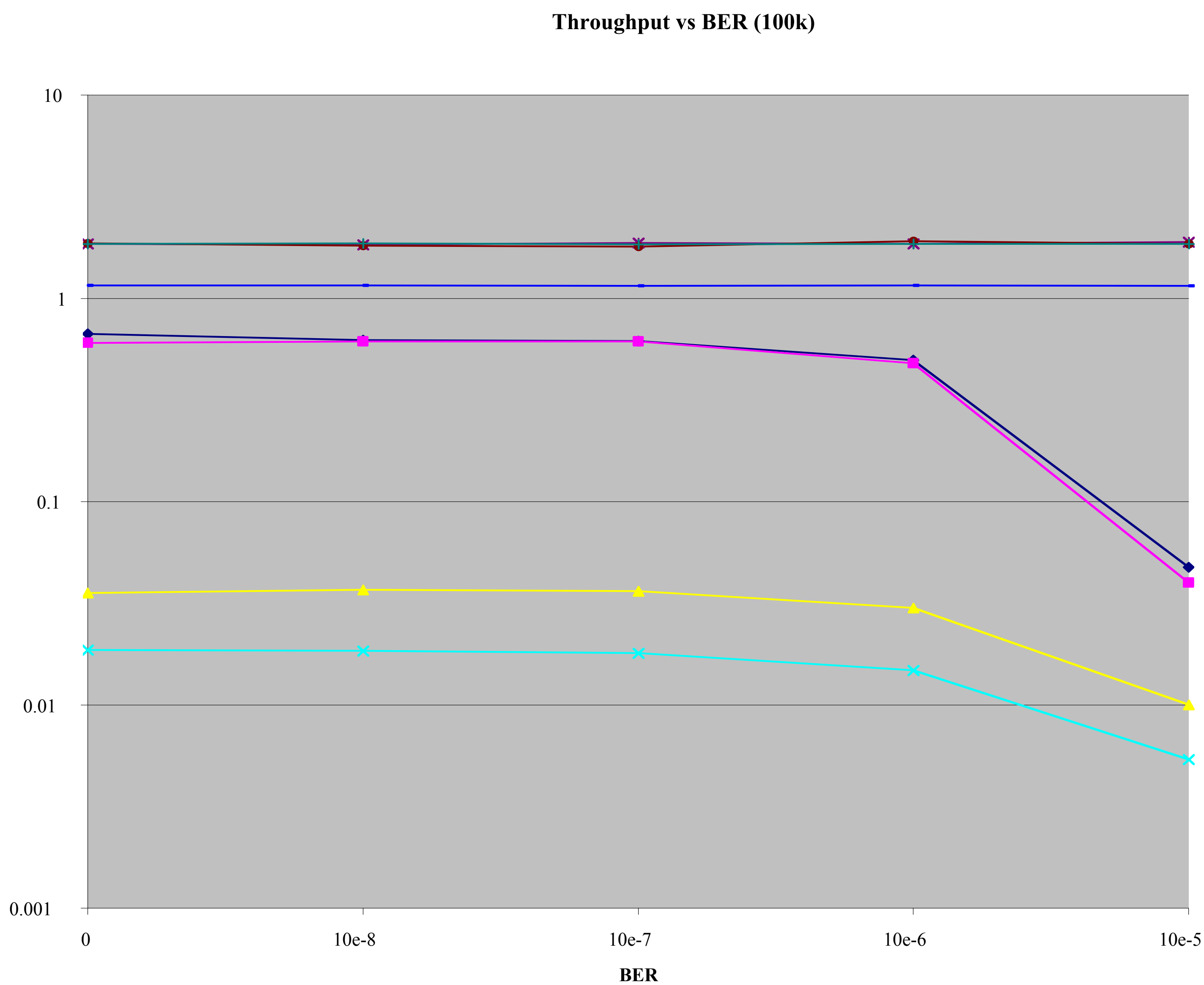
- No bit errors
- 1 bit error every 100,000,000 Bits (10e-8)
- 1 bit error every 10,000,000 Bits (10e-7)
- 1 bit error every 1,000,000 Bits (10e-6)
- 1 bit error every 100,000 Bits (10e-5)

Test with the following delays:

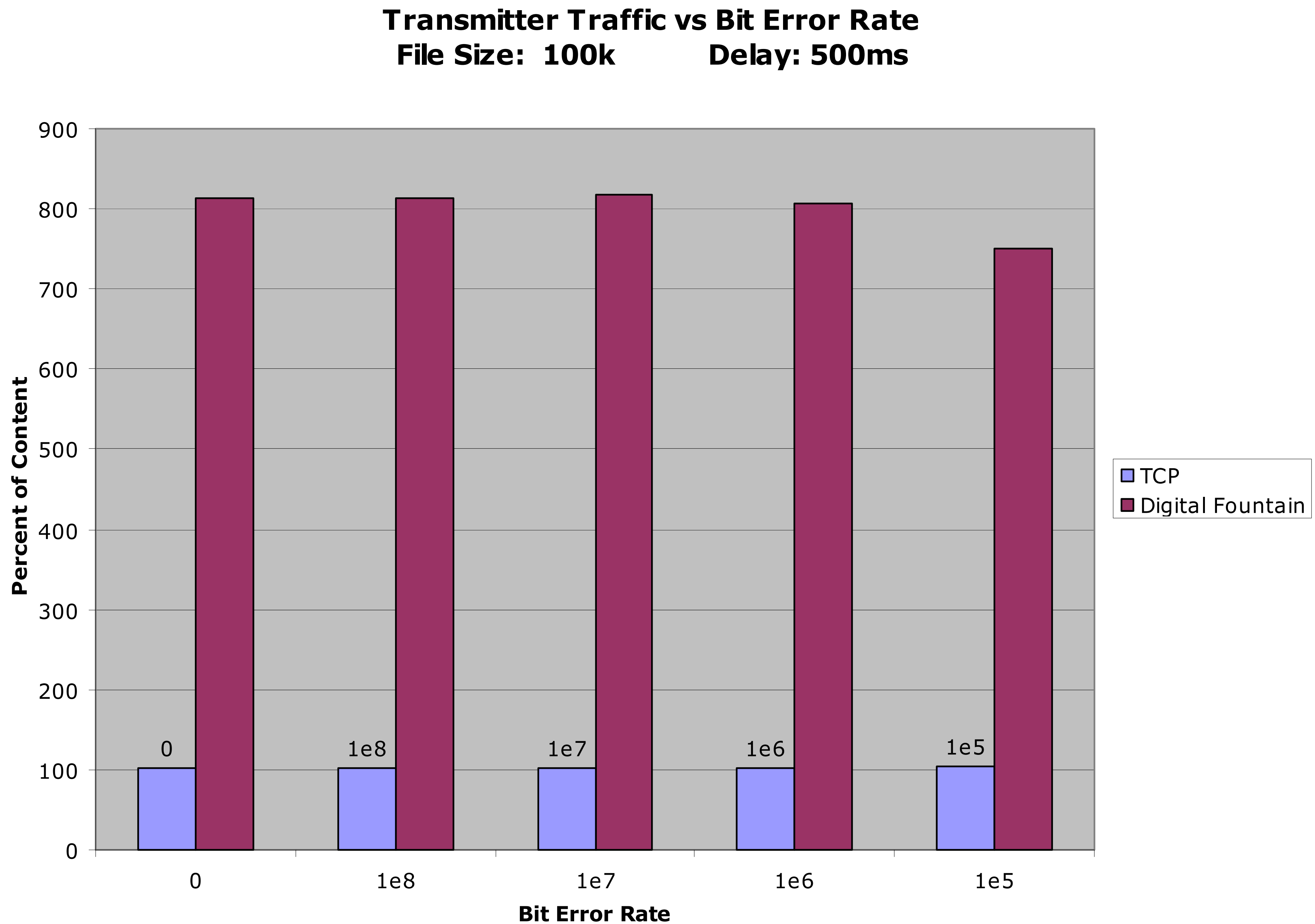
- 0ms
- 10ms
- 250ms
- 500ms

Perform 30 transfers for each derivative of these variables

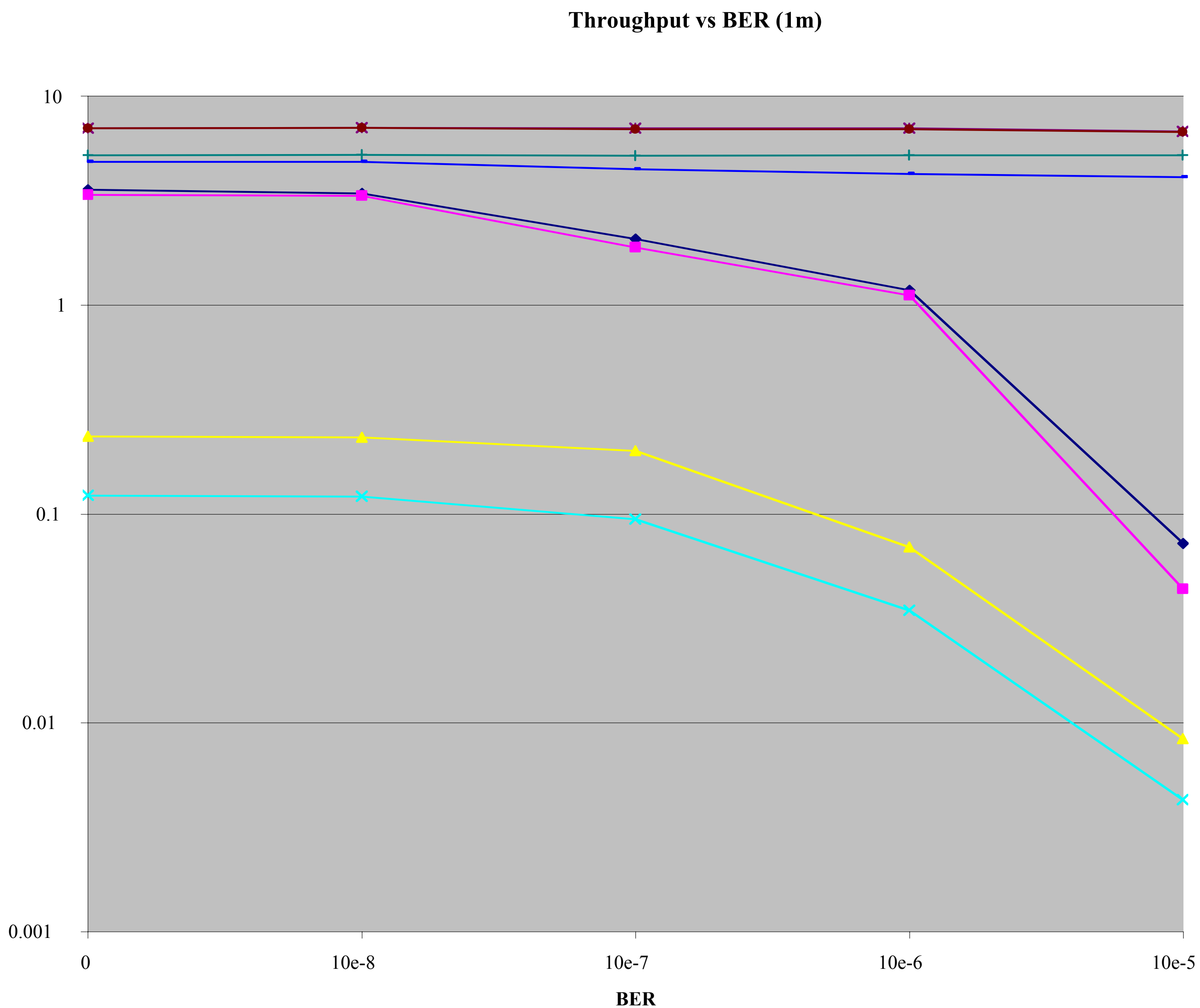
Initial Results



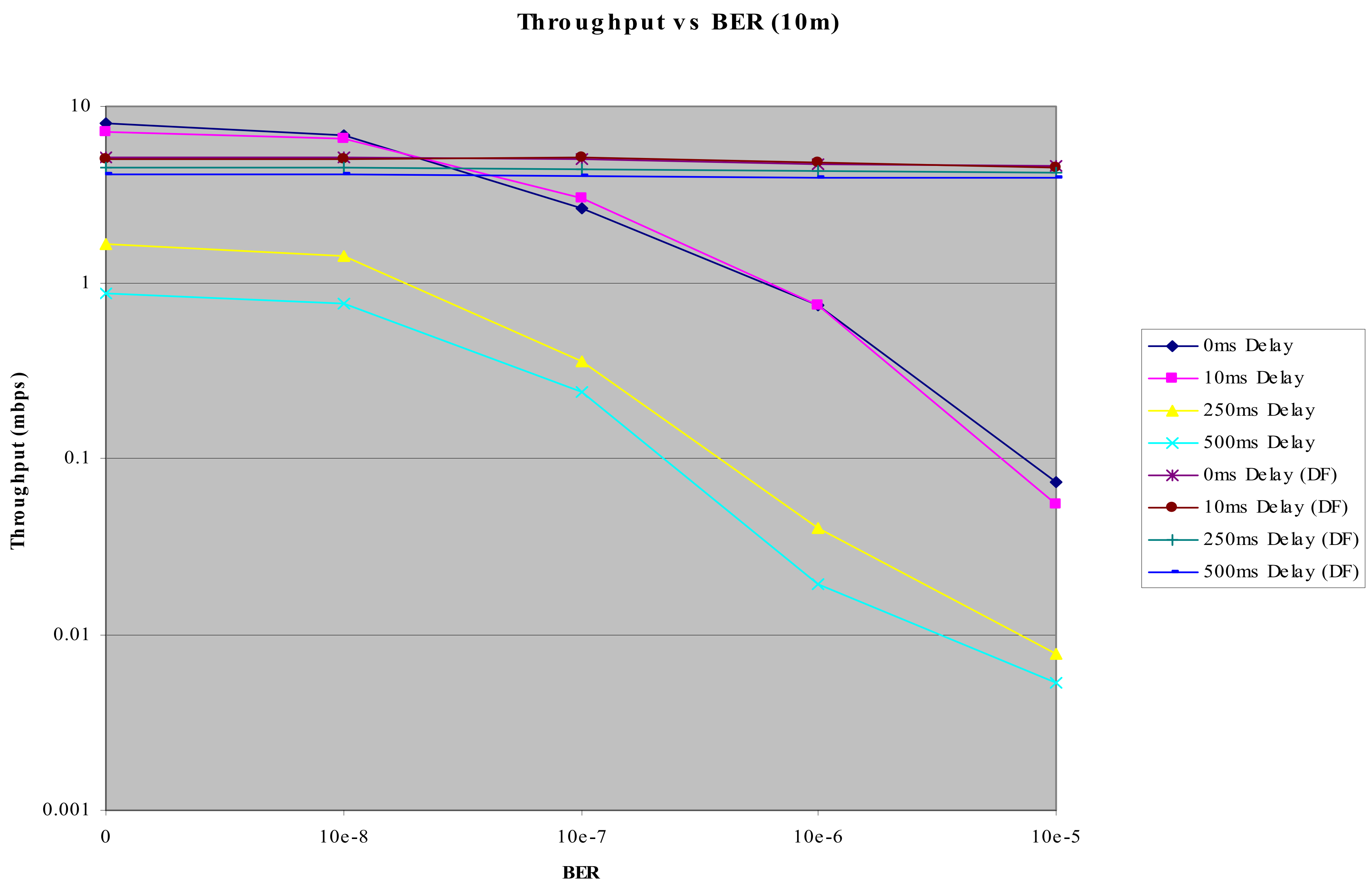
Throughput vs BER (100k)
10
1
0.1
0.01
0.001
0
10e-8
10e-7
10e-6
10e-5
BER

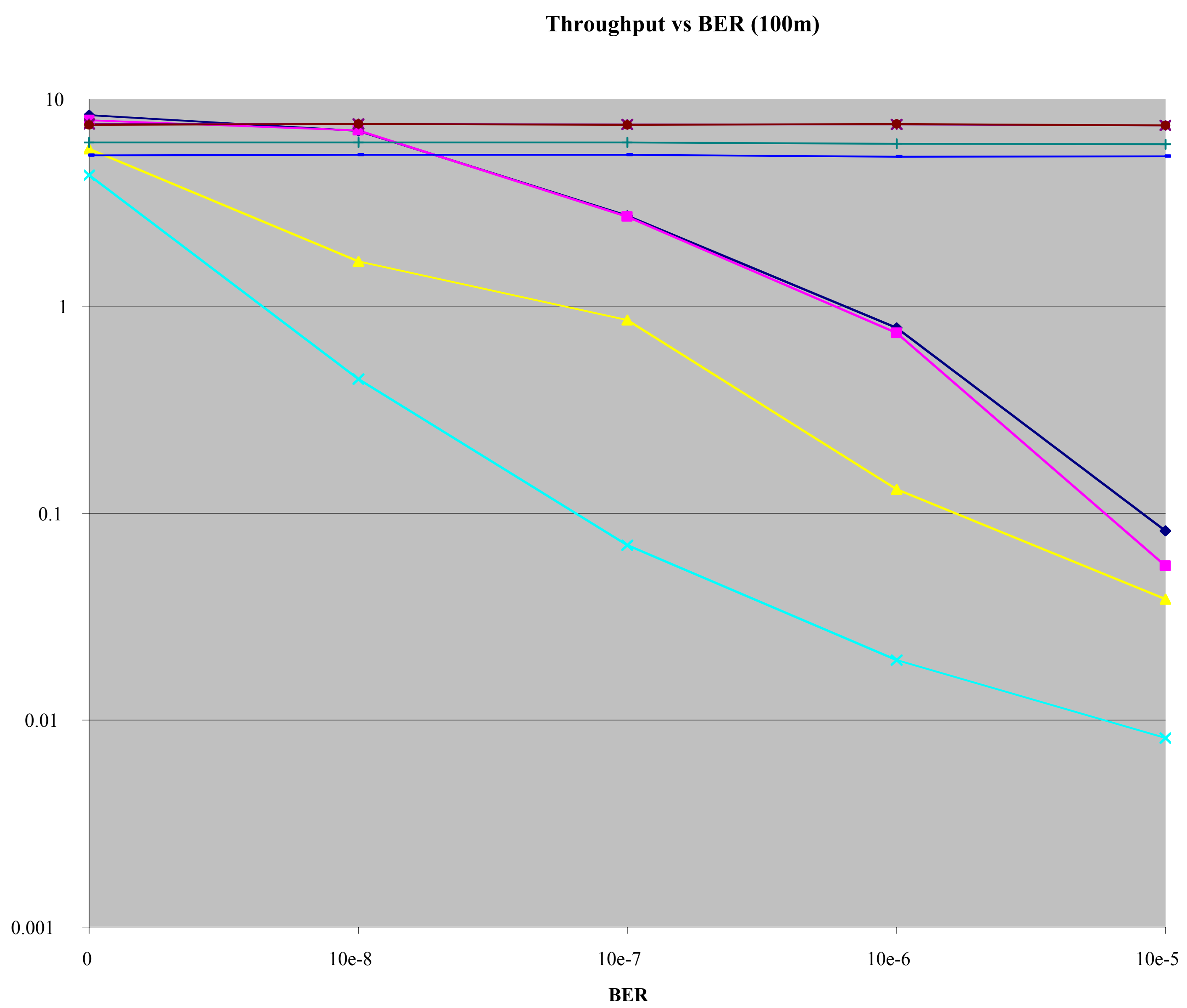


Transmitter Traffic vs Bit Error Rate
File Size: 100k Delay: 500ms
Percent of Content
900
800
700
600
500
400
300
200
100
0
0
1e8
1e7
1e6
1e5
Bit Error Rate
TCP
Digital Fountain



Throughput vs BER (1m)
10
1
0.1
0.01
0.001
0
10e-8
10e-7
10e-6
10e-5
BER


Throughput vs BER (10m)
Throughput (mbps)
10
1
0.1
0.01
0.001
0
10e-8
10e-7
10e-6
10e-5
BER
0ms Delay
10ms Delay
250ms Delay
500ms Delay
0ms Delay (DF)
10ms Delay (DF)
250ms Delay (DF)
500ms Delay (DF)


Throughput vs BER (100m)
10
1
0.1
0.01
0.001
0
10e-8
10e-7
10e-6
10e-5
BER

Transmitter Traffic vs Bit Error Rate
File Size: 100000k Dealy: 500ms
120
115
110
105
100
95
90
Percent of Content
0
1e8
1e7
1e6
1e5
Bit Error Rate
TCP
Digital Fountain

Conclusions
&
Lessons Learned

Conclusions & Lessons Learned

- Our results had data points which resided far enough outside the average that our results were skewed for 10,000KB and 100,000KB tests. These data points were removed for this presentation.

- We need to obtain additional protocol specifications from Digital Fountain for more accurate measurements of the DF process.

- Digital Fountain is more tolerant to BER than TCP and other rate-based protocols.

- Our TCP tests did outperform Digital Fountain on larger file sizes when BER and delay conditions were favorable.

- Performance for smaller file sizes transfers are possibly negated by the receivers processing overhead.

Conclusions & Lessons Learned

Initial observations show Digital Fountain may be a good fit for data delivery in space-based architectures!

Future Work

Future Work

- Test Digital Fountain using planetary delays.

- Run the Digital Fountain product in congestion control mode and compare results to established single TCP flow results.

- Run the Digital Fountain product in congestion control mode and measure the product “fairness” with 1- 3, TCP flows.

- Test Digital Fountain in a large scale multicast environment.

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